Bereskin & Parr
INTELLECTUAL PROPERTY LAW

Appl. No	:	10/517,769	Confirmation No.: 6616
Applicant	:	Thomson et al.	
Filed	:	December 27, 2004	
Title	:	MEASURING STRAIN IN A STRUCTURE USING A SENSOR HAVING AN ELECTROMAGNETIC RESONATOR	
TC./A.U.	:	2855	
Examiner	:	Octavia L. Davis	
Docket No.	:	9157–058	
Customer No.	:	001059	

Honorable Commissioner for Patents
P. O. Box 1450
Alexandria, Virginia 22313–1450

AMENDMENT

Sir:

In response to the office action of May 16, 2006, please amend the above-identified application as follows:

Amendment to the Title begins on page 2 of this paper.

Amendments to the Claims are reflected in the listing of claims, which begins on page 3 of this paper.

Remarks/Arguments begin on page 10 of this paper.

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Amendment to the Title:

Please replace the title, with the following amended title:

MEASURING STRAIN IN A STRUCTURE ~~(BRIDGE) WITH A (TEMPERATURE COMPENSATED)~~ USING A SENSOR HAVING AN ELECTROMAGNETIC RESONATOR ~~(MICROWAVE CAVITY)~~

Amendments to the Claims:

This listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

Claim 1 (currently amended): A system for measuring strain experienced by a structure, said system comprising:

a) a sensor including:

i) a body having an electromagnetic cavity ~~resonator~~, said electromagnetic cavity ~~resonator~~ adapted to produce a response signal in response to an interrogation signal, said body being coupled to said structure to allow said strain to alter the resonance properties of said electromagnetic cavity ~~resonator~~ thereby altering said response signal; and,

ii) a coupler coupled to said body, said coupler adapted to transfer said interrogation signal into said electromagnetic cavity ~~resonator~~ and transfer said response signal out of said electromagnetic cavity ~~resonator~~; and,

b) an interrogator being adapted to generate and transmit said interrogation signal to said sensor, said interrogator being further adapted to receive said response signal.

Claim 2 (currently amended): The system of claim 1, wherein said electromagnetic cavity contains a dielectric ~~resonator is a dielectric resonator~~.

Claim 3 (currently amended): The system of claim 1, wherein said body is a dielectric body ~~electromagnetic resonator is an electromagnetic cavity~~.

Claim 4 (currently amended): The system of claim [[3]] 1, wherein said electromagnetic cavity is rectangular.

Claim 5 (currently amended): The system of claim [[3]] 1, wherein said electromagnetic cavity is cubic.

Claim 6 (currently amended): The system of claim [[3]] 1, wherein said electromagnetic cavity is cylindrical.

Claim 7 (currently amended): The system of claim [[3]] 1, wherein said sensor further comprises a mechanical amplifier coupled to said electromagnetic cavity, said mechanical amplifier being adapted to amplify the magnitude of said strain on said electromagnetic cavity.

Claim 8 (original): The system of claim 7, wherein said mechanical amplifier comprises a first member having a first region with a first length and a second member having a second region with a second length, said second region being coupled to said first region, wherein said first region is exposed to said strain and said second region is coupled to said electromagnetic cavity, wherein the magnitude of said strain experienced by said electromagnetic cavity is amplified by a factor equal to the ratio of said second length to said first length.

Claim 9 (original): The system of claim 1, wherein said interrogator comprises:

a) an antenna for transmitting said interrogation signal and receiving said response signal; and,

b) a signal generator coupled to said antenna, said signal generator being adapted to generate said interrogation signal.

Claim 10 (original): The system of claim 9, wherein said interrogator further comprises a detection module coupled to said antenna, said detection module being adapted to process said response signal to determine a value indicative of said strain.

Claim 11 (original): The system of claim 10, wherein said interrogator further comprises:

a) an output module coupled to said control module, said output module being adapted to provide an output indicative of said strain; and,

b) a control module coupled to said signal generator, said detection module and said output module for controlling the operation thereof.

Claim 12 (original): The system of claim 11, wherein said interrogator further comprises:

a) a memory module in communication with said signal generator, said detection module and said control module, said memory module being adapted to store information related to previously determined strains; and,

b) an input module in communication with said control module, said input module being adapted to allow a user to operate said interrogator.

Claim 13 (currently amended): The system of claim 10, wherein said interrogation signal is a continuous narrowband signal having a center frequency that is varied in a sweep range that includes a resonant frequency of said electromagnetic cavity ~~resonator~~ and said detection module is adapted to detect a minimum in said response signal at a frequency within said sweep range, wherein said minimum occurs at said resonant frequency.

Claim 14 (currently amended): The system of claim 10, wherein said interrogation signal is a broadband signal having a frequency content that includes a resonant frequency of said electromagnetic cavity ~~resonator~~, and said detection module is adapted to detect a minimum in said response signal wherein said minimum occurs at said resonant frequency.

Claim 15 (currently amended): The system of claim 10, wherein said interrogation signal is a modulated narrowband signal having a center frequency that is varied in a

sweep range that includes a resonant frequency of said electromagnetic cavity ~~resonator~~ and said detection module is adapted to detect a peak in said response signal at a frequency within said sweep range, wherein said peak occurs at said resonant frequency.

Claim 16 (currently amended): The system of claim 10, wherein said interrogation signal is a modulated broadband signal having a frequency content that includes a resonant frequency of said electromagnetic cavity ~~resonator~~, and said detection module is adapted to detect a peak in said response signal wherein said peak occurs at said resonant frequency.

Claim 17 (currently amended): A sensor for measuring strain experienced by a structure, said sensor comprising:

a) a body having an electromagnetic cavity ~~resonator~~ for producing a response signal in response to an interrogation signal, said body being coupled to said structure to allow said strain to alter the resonance properties of said electromagnetic cavity ~~resonator~~ thereby altering said response signal; and,

b) a coupler coupled to said sensor, said coupler adapted to transfer said interrogation signal into said electromagnetic cavity ~~resonator~~ and transfer said response signal out of said electromagnetic cavity.

Claim 18 (currently amended): The sensor of claim 17, wherein said electromagnetic cavity contains a dielectric ~~resonator is a dielectric resonator~~.

Claim 19 (currently amended): The sensor of claim 17, wherein said said body is a dielectric body ~~electromagnetic resonator is an electromagnetic cavity~~.

Claim 20 (currently amended): The sensor of claim [[19]] 17, wherein said electromagnetic cavity is rectangular.

Claim 21 (currently amended): The sensor of claim [[19]] 17, wherein said electromagnetic cavity is cubic.

Claim 22 (currently amended): The sensor of claim [[19]] 17, wherein said electromagnetic cavity is a cylindrical cavity.

Claim 23 (currently amended): The sensor of claim [[19]] 17, wherein said sensor further comprises a mechanical amplifier coupled to said electromagnetic cavity, said mechanical amplifier being adapted to amplify the magnitude of said strain on said electromagnetic cavity.

Claim 24 (original): The sensor of claim 23, wherein said mechanical amplifier comprises a first member having a first region with a first length and a second member having a second region with a second length, said second region being coupled to said first region, wherein said first region is exposed to said strain and said second region is coupled to said electromagnetic cavity, wherein the magnitude of said strain experienced by said electromagnetic cavity is amplified by a factor equal to the ratio of said second length to said first length.

Claim 25 (currently amended): A method for measuring strain experienced by a structure, said method comprising:

a) coupling a sensor to the structure, the sensor having an electromagnetic cavity ~~resonator~~;

b) transferring through a coupler an interrogation signal into said electromagnetic cavity ~~resonator~~ to evoke a response signal; and,

c) transferring through the same or a different coupler said response signal out of said electromagnetic cavity ~~resonator~~.

Claim 26 (original): The method of claim 25, wherein said method further comprises processing said response signal to determine said strain.

Claim 27 (currently amended): The method of claim 25, ~~wherein said electromagnetic resonator is an electromagnetic cavity and~~ said method further comprising ~~comprises~~:

d) amplifying said strain in a mechanical fashion to amplify the magnitude of said strain experienced by said electromagnetic cavity.

Claim 28 (currently amended): The method of claim 25, wherein step b) comprises:

e) providing said interrogation signal as a continuous narrowband signal; and,

f) sweeping the center frequency of said narrowband signal in a sweep range that includes a resonant frequency of said electromagnetic cavity ~~resonator~~.

Claim 29 (currently amended): The method of claim 28, wherein step c) comprises processing said response signal to detect a minimum at a frequency within said sweep range indicative of the resonant frequency of said electromagnetic cavity ~~resonator~~.

Claim 30 (currently amended): The method of claim 25, wherein step b) comprises:

a) providing said response signal as a continuous broadband signal having a frequency content that includes a resonant frequency of said electromagnetic cavity ~~resonator~~.

Claim 31 (currently amended): The method of claim 30, wherein step c) comprises processing said response signal to detect a notch at a frequency indicative of the resonant frequency of said electromagnetic cavity ~~resonator~~.

Claim 32 (currently amended): The method of claim 25, wherein step b) comprises:

e) modulating said interrogation signal to provide an intermittent narrowband signal; and,

f) sweeping the frequency of said intermittent narrowband signal in a sweep range that includes a resonant frequency of said electromagnetic cavity ~~resonator~~.

Claim 33 (currently amended): The method of claim 32, wherein step c) comprises processing said response signal to detect a peak at a frequency within said sweep range indicative of the resonant frequency of said electromagnetic cavity ~~resonator~~.

Claim 34 (currently amended): The method of claim 25, wherein step b) comprises:

a) modulating said interrogation signal to provide an intermittent broadband signal having a frequency content that includes a resonant frequency of said electromagnetic cavity ~~resonator~~.

Claim 35 (currently amended): The method of claim 34, wherein step c) comprises processing said response signal to detect a peak at a frequency indicative of the resonant frequency of said electromagnetic cavity ~~resonator~~.

REMARKS/ARGUMENTS

This is in response to the Examiner's communication dated May 16, 2006.

I. Introduction

Claims 1–35 are pending in the above application.

Claims 1–6, 9–22, 25, 26 and 28–35 stand rejected under 35 U.S.C. §102(b).

Claims 7, 8, 23, 24 and 27 stand rejected under 35 U.S.C. §103(a).

II. Amendments

The applicant has amended the title to more accurately reflect the invention.

The applicant has amended independent claims 1, 17 and 25 to more clearly claim the invention in view of the Examiner's objections. Applicant has also made minor voluntary amendments to dependant claims 2–7, 13–16, 18–24 and 27–35 to be consistent with the amended independent claims presented herewith.

III. Rejection Under 35 U.S.C. §102(b)

Claims 1–6, 9–22, 25, 26 and 28–35 stand rejected under 35 U.S.C. §102(b) as being anticipated by Gershenfeld et al. (6,025,725). Applicant respectfully traverses this rejection. Anticipation under 35 U.S.C. §102 requires that each and every element of the claim be disclosed in a prior art reference as arranged in the claim. See *C. R. Bard, Inc. v. M3 Sys., Inc.*, 157 F. 3d 1340, 1349, 48 USPQ 2d (Fed. Cir. 1998); and *Connell v. Sear, Roebuck & Co.*, 220 USPQ 193, 198 (Fed. Cir. 1983).

In Applicants' invention a resonant electromagnetic cavity is used, not a resonant LC circuit as disclosed and taught by Gershenfeld et al. For the monitoring of civil structures, it is important to have high strain resolution (ppm) and very good long term strain stability (5–10 ppm). For example, a large truck running over a medium sized bridge will typically produce strains of 10–50 ppm. This level of stability cannot be reasonably achieved with LRC resonators; C depends on many factors which can not be controlled to ppm levels over periods of years, L depends on many factors which can not be controlled to ppm levels over many years, and LC circuits can not achieve as high a Q as can be achieved in a cavity resonator. Applicants submit that Gershenfeld et al. recognized this and in their patent explicitly laid out arguments and experimental results showing the difficulty of using dimensional changes alone to measure strain:

> "To appreciate the utility of the present invention in force-sensing applications, it is useful to model the response of a resonator constructed as shown in FIGS. 1A and 1B, but containing a conventional high-frequency dielectric (such as clear TEFLON in sheet form). The structure can be accurately represented as a simple LRC circuit including an inductor, resistor and plate capacitor with a dielectric material. By applying an elastic model to the deformation of the dielectric material under applied stress, the resonant frequency of the tag can be derived as a function of applied stress:
>
> $$\omega_n = \omega_{n_0}\sqrt{\frac{\mathrm{E}-\sigma}{\mathrm{E}}}$$
>
> where ω_{n_0} is the resonant frequency of the tag absent any applied stress, E is the Young's Modulus of the dielectric material, and a is the applied stress. Rearranging this equation yields an expression relating the ratio of the change of resonant frequency versus initial resonant frequency and the induced strain, $\in$, in the dielectric material:

$$\frac{\Delta\omega}{\omega_{n_0}} = 1 - \sqrt{1-\varepsilon}$$

"The measured data and the curve predicted by this model is included in FIG. 8 (discussed below) and very closely matched the measured data to within 0.1%. On this frequency scale, the change in resonant frequency appears as a flat line." Column 7, lines 22–53.

In the last line Gershenfeld et al. essentially concludes that it is not possible to measure strain with dielectrics such as Teflon^{TM}. Gershenfeld et al. tries to convince the reader that strain can only be measured through the use of piezoelectric or similar dielectric materials. Applicant notes that Gershenfeld et al. uses the terms "LC-resonator," "LC-tank circuit," "LRC-resonator," "LC-package," and "flat LC-resonator package" in all Figures to their device. An LC-resonator is a resonant lumped circuit resonator device comprising of components that act as separate inductor (L) and capacitor (C) lumped element circuit components. Each element stores energy separately, with the energy oscillating between the components during resonance. The lumped L component typically has the highest loss (contributing to the R in the LRC-resonator) associated with its implementation due to current that flows through a conductor in an inductor (Gershenfeld et al. uses spiral L components in all drawings). This loss, results in a low Q-factor, and is the reason that strain cannot be measured using a dielectric LC-resonator as argued by Gershenfeld et al.

Applicants' invention discloses a different type of resonator, namely, an electromagnetic cavity resonator. Applicants' invention is distinct from the lumped element LC-resonator device of Gershenfeld et al. in its fundamental operation. In an electromagnetic cavity, energy is stored simultaneously in the coupled electric-magnetic field within a confining cavity (metallic encasement). If an air dielectric fills the cavity the fields experience no loss (except at the confinement walls of the cavity) and subsequently a very high Q-factor can be achieved (typically 10 times or more than with a lumped element LC resonator). Distinct from a lumped element LC-resonator, the

electromagnetic cavity geometry and dimensions can be designed to be resonant for different electromagnetic field configurations and frequencies. This enables the cavity to be tailored to a specific desired property and coupling approach.

For anticipation, "[t]he identical invention must be shown in as complete detail as is contained in the . . . claim." *Richardson v. Suzuki Motor Co.*, 868 F.2d 1226, 1236, 9 USPQ2d 1913, 1920 (Fed. Cir. 1989). Moreover, the elements must be arranged as required by the claim. *In re Bond*, 910 F.2d 831, 15 USPQ2d 1566 (Fed. Cir. 1990).

Geshenfeld et al. does not disclose, as now claimed in independent claims 1 and 17 and 25, a system, sensor and method for measuring strain experienced by a structure, where the sensor includes a body having an electromagnetic cavity, the electromagnetic cavity adapted to produce a response signal in response to an interrogation signal, the body being coupled to the structure to allow the strain to alter the resonance properties of the electromagnetic cavity thereby altering the response signal, and a coupler coupled to the body, the coupler adapted to transfer the interrogation signal into the electromagnetic cavity and transfer the response signal out of the electromagnetic cavity, and an interrogator being adapted to generate and transmit the interrogation signal to the sensor, the interrogator being further adapted to receive the response signal. Accordingly Gershenfeld et al. does not anticipate the invention as now claimed.

The dependent claims depend from these claims and therefore incorporate the limitations recited above with respect to the independent claims. Accordingly, applicant submits that the dependent claims are not anticipated by the Gershenfeld et al. reference.

IV. Rejection Under 35 U.S.C. §103(a)

Claims 7, 8, 23, 24 and 27 stand rejected under 35 U.S.C. §103(a) as being unpatentable over Gershenfeld et al. in view of Spillman, Jr. (5,440,300). Applicant respectfully traverses this rejection.

As previously mentioned, Gershenfeld et al. essentially concludes (col. 7, lines 22–53) that it is not possible to measure strain with dielectrics such as Teflon™. Gershenfeld et al. tries to convince the reader that strain can only be measured through the use of piezoelectric or similar dielectric materials. However, these materials suffer from serious hysterisis, thermal drift and aging problems. Applicants' submit that this provides convincing evidence that one skilled in the art would not see the use of resonant cavities as an obvious extension of Gershenfeld et al.'s teachings. Gershenfeld et al. does not teach applicants' invention; rather, applicants' submits, Gershenfeld et al. teaches away from the present invention. Accordingly, there can be no prima facie case of obviousness of modifying Gershenfeld et al. as suggested by the Examiner to provide the invention. In this regard see *In re Pye*, 148 USPQ 426, 429 (CCPA 1966) wherein the court held:

> "While, as an abstract proposition, it might be possible to select certain statements from Fikentscher a mechanically combined and with Touey to arrive at appellants' claimed combination, we find absolutely no basis for making such a combination. Neither reference is directed to the problem solved by appellants' invention, namely developing a cleaning composition for the skin having improved lubricity characteristics. In our view only appellants' specification suggests any reason for combining the teachings of the prior art but use of such suggestion is, of course, improper under the mandate of 35 U.S.C. 103. In re Schaffer, 43 CCPA 758, 229 F.2d 476, 108 USPQ 326." (emphasis added)."

Applicant submits that there is no motivation to modify Gershenfeld et al. to provide the invention. Gershenfeld et al. nowhere recognizes the advantages of the

present invention. Without a suggestion of these advantages Gershenfeld et al. cannot be obviously modified. See *In re Gordon*, 221 USPQ 1125, 1127 (Federal Circuit 1984):

> "We are persuaded that the board erred in its conclusion of prima facie obviousness...The mere fact that the prior art could be so modified would not have made the modification obvious unless the prior art suggested the desirability of the modification."

Moreover, for the Spillman, Jr. et al. invention, it is assumed that the signal is digitized and processed within the embedded sensor before it is transmitted. Applicants' sensor does not rely on digitizing the signal and the sensing information is contained in the analog signal itself with no need for digital electronics, which would require additional elements to process and digitize the sensor signal. This adds considerable complexity and cost to the sensor. Additionally, it also limits the interrogation of the embedded sensor to the specific data transfer protocol implemented in the embedded sensor. This could be a considerable problem for civil structures where sensors may be embedded for decades. There is a very real possibility that the specific protocol used could become obsolete and the electronic components needed to transfer data could become unavailable and unsupported.

Accordingly, in applicants submission, there is not even the most remote suggestion in any way, shape or form of modifying the Gershenfeld et al. method or apparatus either singly or combined with Spillman, Jr. et al., for the purposes of the present invention as described and now claimed.

Applicant submits that this case is in condition for allowance. However, should the Examiner have any concerns with the claims as amended, applicant invites the Examiner to call the undersigned at (416) 957-1697 to discuss the case and avoid the expense and time of issuing a further communication.

Respectfully submitted,

BERESKIN & PARR

By ______________________

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